Chapter 2: The Scientific Method, Overview of Life, and the Chemistry of Life

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Essential Question:

What are the basic chemical principles that affect living things?

What procedures are at the core of scientific methodology?

Steps in the scientific method

- 1. **Stating a problem**
  - Occurs when someone observes an event in nature and wonders "why" or "how" it occurs.
- 2. **Researching and gathering information**
  - This functions to provide as much background information as possible
- 3. **Forming a hypothesis**
  - A **hypothesis** *is a possible explanation for a problem using what you know and what you observe.*
    - Typically it is written as an "if ____ then _____" statement

- 4. **Testing a hypothesis**
  - The results collect either support or do not support the hypothesis.
  - Some hypotheses can be tested through observation and others by performing an experiment. An **experiment** *tests the effect of one thing on another using controlled conditions*.
    - An experiment usually contains at least 2 variables. A **variable** *is a factor that can cause a change in the results of an experiment.*
      - 1. **Independent variable-** *this is the variable that can be changed by the experimenter.* A good experiment will only have ONE. You can consider this the "cause"
      - 2. **Dependent variable-** *this is the factor that can change if the independent variable changes.* Thus, this variable changes in response to the independent variable. You can consider this the "effect" or data being collected or the result.

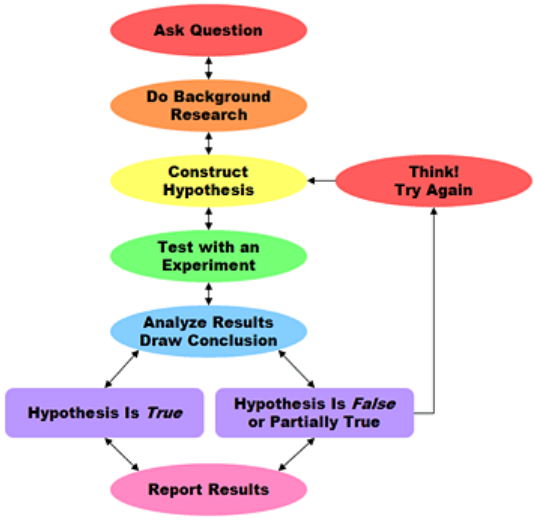
3. **Constants-** *factors that do not change in an experiment.* By keeping all other variables the same but the independent variable, you ensure the accuracy of your results and that the outcome of the experiment is only due to one thing- the independent variable.
4. **Control-** *is used in an experiment to show that the results of an experiment are actually a result of the condition being tested*. It is a standard used for comparison.

5. **Analyzing the data**
   - Data is organized in a logical manner through graphs and tables.
- 6. **Drawing conclusions**
  - Based on the data you decide whether or not your hypothesis was supported.
- NOTE!
  - Scientists should be careful to reduce bias in an experiment
    - **Bias** *occurs when what the scientist expects changes how the results are viewed.*
    - It can be avoided by repeating the experiment several times.

Types of data

- **Quantitative data-** *is numerical*
  - Ex. 5g, 67mg, 10,000 repetitions, etc.
- **Qualitative data-** *is based on the alphabet*
  - Ex. red, blue, singing, etc.
- Observation vs. inference
  - **Observation** *is the process of gathering objective data*, and **inference** *is the process of making some decisions about what the data means or a logical interpretation based on prior knowledge or experiences.*

Steps in the scientific method



QUESTION AND ANSWER

What procedures are at the core of scientific methodology?

What characteristics do all living things share?

Abiogenesis vs. Biogenesis

Biogenesis	The principle that living organisms develop only from other living organisms and not from nonliving matter.
Abiogenesis	The supposed development of living organisms from nonliving matter. Also called autogenesis, spontaneous generation.

Characteristics of living things

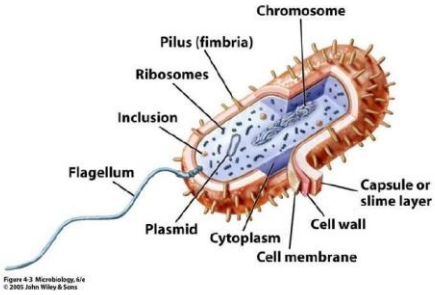
1. Made up of cells
   - **Prokaryotes**- do not have a nucleus or membrane-bound organelles except ribosomes, ex. bacteria
     - Can belong to either Domain Archae or Domain Bacteria
   - **Eukaryotes**- has a nucleus and membrane-bound organelles , ex. animals, plants, fungi, and protists
     - Belongs to Domain Eukarya
2. Reproduce- either through asexual or sexual reproduction
   - **sexual reproduction,** in which cells from two parents unite to form the first cell of a new organism.
   - **asexual reproduction,** in which a single organism produces offspring identical to itself.
3. Based on universal genetic code- DNA
4. Grow and develop

Characteristics of living things

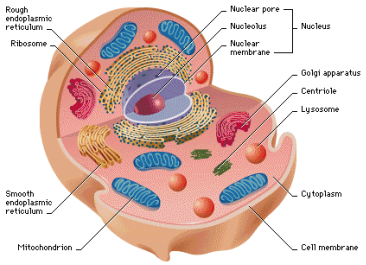
5. Obtain and use materials and energy
   - ***Metabolism*** refers to all the physical and chemical processes in the body that convert or use energy, such as breathing and circulating blood.
   - ***Catabolism*** is the breaking down of things - a series of degradative chemical reactions that break down complex molecules into smaller units, and in most cases releasing energy in the process.
   - ***Anabolism*** is the building up of things - a succession of chemical reactions that constructs or synthesizes molecules from smaller components, usually requiring energy in the process.
6. Respond to their environment- **adaptations.**
7. Maintain a stable environment or **homeostasis**
8. Change over time

Examples of a Prokaryote and Eukaryotes

Prokaryote
Ex. bacteria



Eukaryotes
Ex. animals, plants, protists, and fungi



QUESTION AND ANSWER

What characteristics do all living things share?

What are the 3 subatomic particles that makeup an atom and their charges?

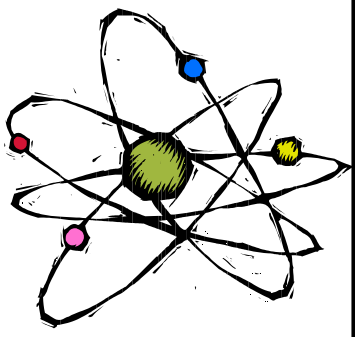
Atoms

- All living things are made up of matter
- **Atoms** are the smallest unit of matter
  - Are made up of 3 subatomic particles:
    - 1. protons- positively charged, found in the nucleus, has mass
    - 2. neutrons- neutral charged/ no charge, found in the nucleus, same mass as proton
    - 3. electrons- negatively charged, has little mass

The Nature of Matter

Atoms

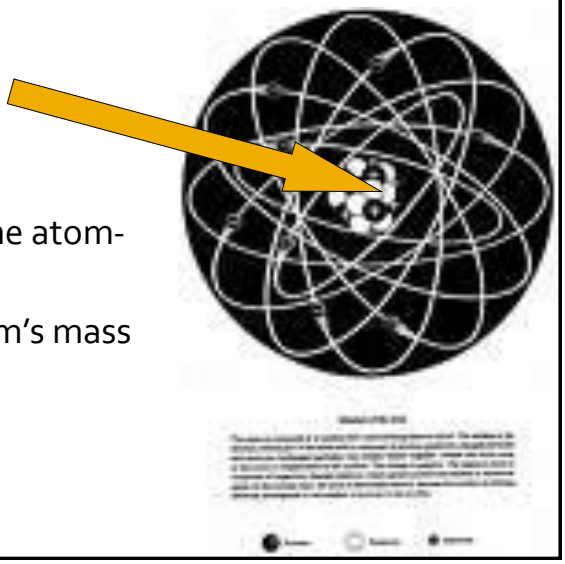
- All things are made of matter
- Basic unit of all matter-atom
- Parts of the atom
  - Protons
  - Neutrons
  - Electrons



The Nature of Matter

Protons

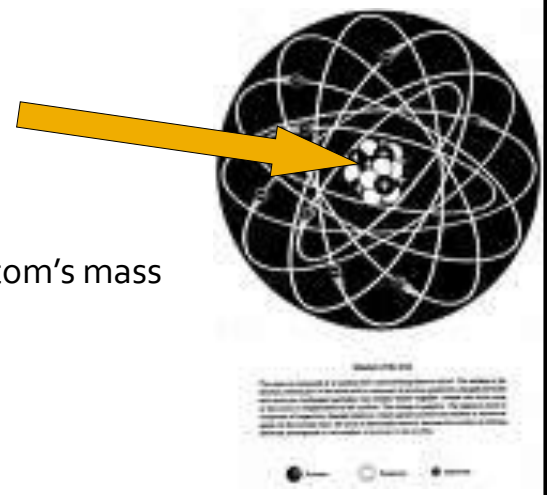
- Protons
  - + charged
  - In the center of the atom-nucleus
  - Major part of atom's mass



The Nature of Matter

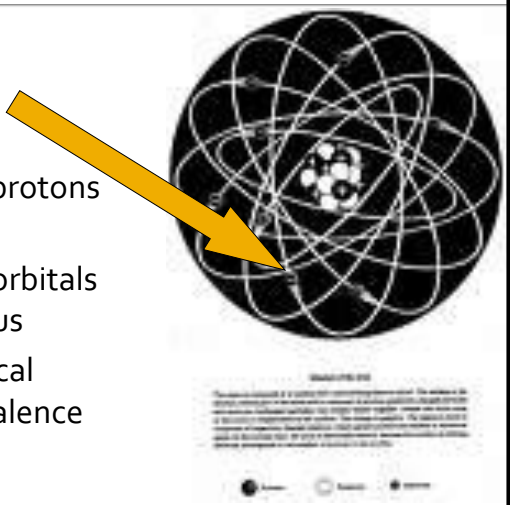
Neutrons

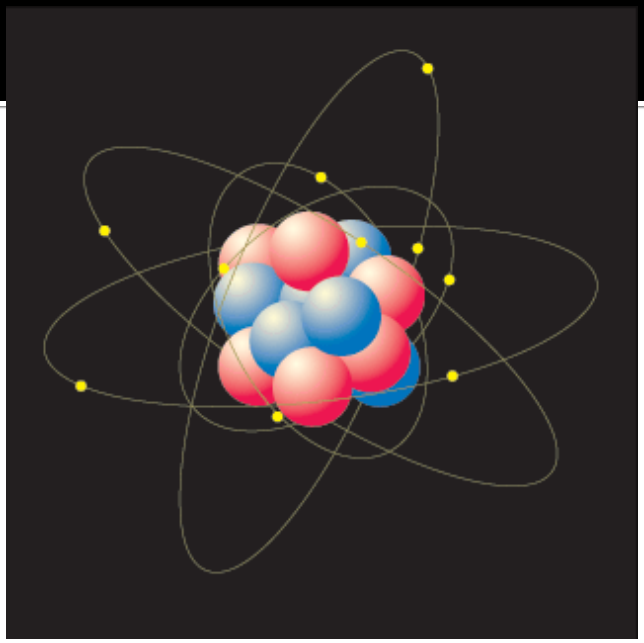
- Neutrons
  - Neutral charge
  - In the nucleus
  - Major part of an atom's mass



The Nature of Matter

- Electrons
  - - charged
  - 1/1840 of the mass of protons and neutrons
  - In constant motion in orbitals surrounding the nucleus
  - Responsible for chemical properties of atom—valence electrons

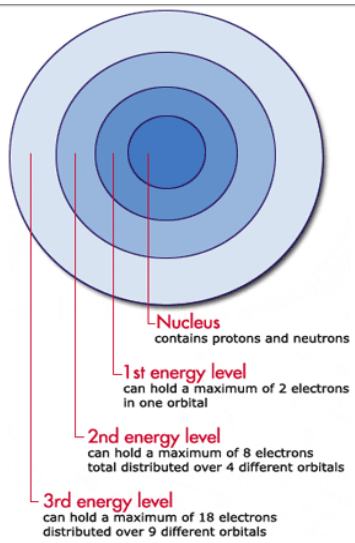




Atoms (con't)

- The size of an atom depends mostly on the number and arrangement of its electrons but its mass depends mostly on the number of protons and neutrons
- **An energy level** represents the area in an atom where an electron is most likely to be found.
  - Each energy level can hold a limited amount of electrons, ex. Innermost= 2, the 2nd= 8, 3rd= 18, 4rth= 32
- The electrons in the outermost energy level determine the chemical behavior of the different elements.

Energy levels of an atom



Explain the arrangement of the periodic table

Atomic symbols

- **An element** is a pure substance that consists entirely of one type of atom.
  - 114 in the periodic table
  - Are represented by a one or two-letter symbol
- **Atomic symbol:** one or two letters used to represent an element, ex. The symbol "H" stands for a hydrogen atom and the symbol "Na" stands for a sodium atom.
  - These atomic symbols are shown in the Periodic Table

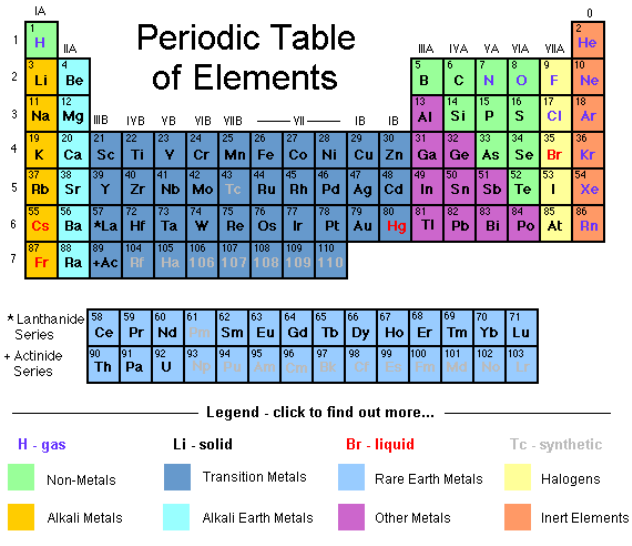
QUESTION AND ANSWER

What are the 3 subatomic particles that makeup an atom and their charges?

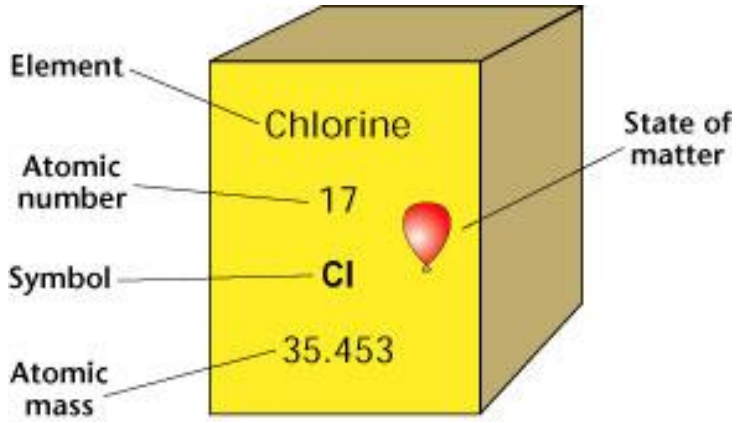
The Periodic Table

- **The Periodic Table** is a tabular display of elements
  - Elements are listed in order of increasing atomic number. Atomic number increases as you move across a row or period.
  - Rows are arranged so that elements with similar properties fall into the same columns. Elements within a group share several common properties. Groups are elements have the same outer electron arrangement. The outer electrons are called **valence electrons**. Because they have the same number of valence electrons, elements in a group share similar chemical properties.
  - Elements lacking valence electrons are said to be inert- which means they do not easily combine with other elements because they have full outermost energy levels

The periodic table of elements



Periodic table (con't)

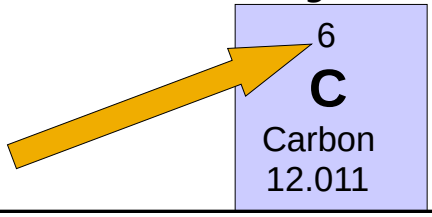


The Nature of Matter

Elements

Atomic Number

- Atomic Number = # protons
- Unique to that element's atoms
- Normally the atomic number= #of protons =# of electrons so the atoms are uncharged



Atomic number and weight

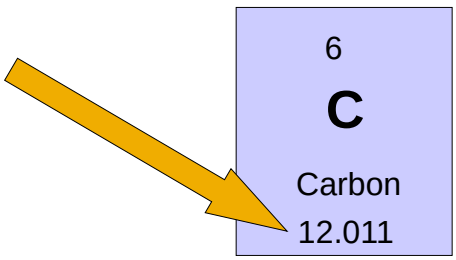
- **Atomic number:** # of protons in an atom.
  - The number of protons contributes to the physical properties (weight) of an atom as well as indirectly determining the chemical properties.
  - All the atoms of a particular element have the same atomic number, which tells the number of protons. The number is often written as a subscript at the lower left of the atomic symbol. The atomic weight (mass) is often written as a superscript at the upper left of the atomic symbol.
- **Atomic weight:** combined weight of protons and neutrons in an atom. Electrons weigh 1/1800 of a proton or neutron so it is customary to disregard the combined weight of the electrons.

The Nature of Matter

Elements

Atomic Mass

- Atomic mass = # protons + # neutrons
- How much mass the atom has
- Only protons and neutrons have considerable mass



FYI

- The chemical properties of atoms differ because the # and arrangement of their electrons is different.

QUESTION AND ANSWER

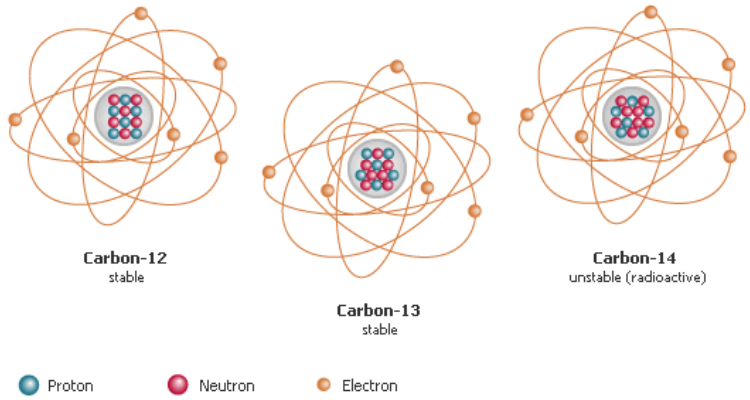
Explain the arrangement of the periodic table

Explain how all of the isotopes of an element are similar and how they are different.

Isotopes

- Atoms that have the same atomic number and differ only by the number of neutrons are called **isotopes**.
- Isotopes are identified by their **mass number** (sum of # of protons and neutrons). Ex. Carbon (C): C-12, C-13, C-14
- All isotopes have the same chemical properties because they have the same number of electrons
  - Most are stable, but a few are unstable and tend to break down to more stable forms. They emit radiation as they break down and thus are radioactive.

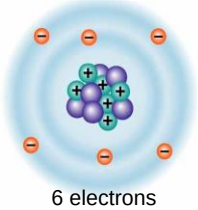
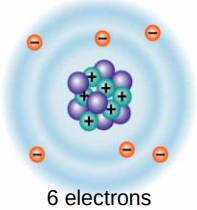
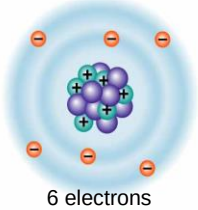
Isotopes of Carbon



The Nature of Matter

- Isotopes-atoms of same element w/ a different # of neutrons
- Atomic # same, atomic mass different
- Identified by their atomic mass

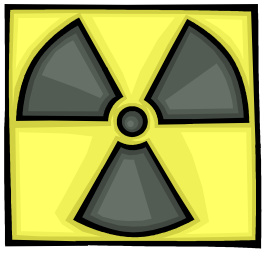
Isotopes of Carbon

Nonradioactive carbon-12	Nonradioactive carbon-13	Radioactive carbon-14
		
6 electrons 6 protons 6 neutrons	6 electrons 6 protons 7 neutrons	6 electrons 6 protons 8 neutrons

The Nature of Matter

Radioactive Isotopes

- Isotopes with unstable nuclei
  - Break down at a constant rate
  - Give off dangerous radiation
  - Have uses too
    - C-14 dating
    - Cancer treatment



QUESTION AND ANSWER

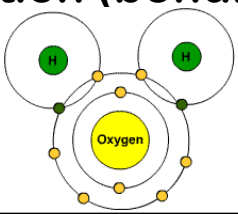
Explain how all of the isotopes of an element are similar and how they are different.

Describe the 2 main types of chemical bonds.

The Nature of Matter

Bonding

- For some atoms to be stable they must gain, lose, or share electrons- bonding.
- Compounds-a substance formed by the chemical combination (bonding) of 2 or more elements



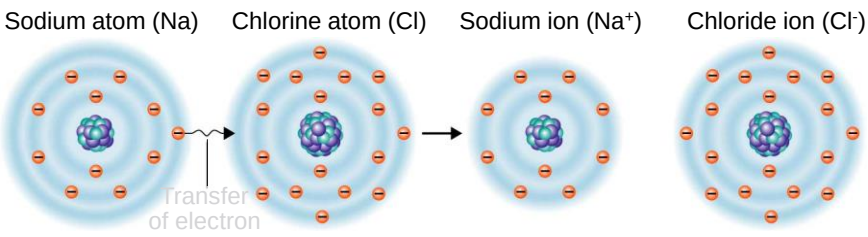
Chemical compounds

- **A chemical compound** is a substance formed by the chemical combination of 2 or more elements in definite proportions. Ex, water
  - Physical and chemical properties differ from elements that composes the compound
  - **Chemical bonds** are forces that hold the elements together in a compound.
  - Atoms held together by chemical bonds that are joined by **valence electrons** (electrons available for bonding)
  - 2 main types of chemical bonds:
    - 1. ionic bond
    - 2. covalent bond

Ionic and covalent bonds

- **An ionic bond** is formed when one or more electrons are transferred from one atom to another
  - **Ions** are positively or negatively charged atoms
  - Ex. Na^+ sodium which loses a valence electron is an ion and Cl^- chloride ion gains an electron forming salt (NaCl)
- **A covalent bond** forms when electrons are shared between atoms.
  - When atoms are joined together by a covalent bond, a **molecule** is formed
    - (**A Molecule** is composed of 2 or more atoms held together by covalent bonds)
      - Represented by chemical formulas that include the symbol for each element followed by a subscript number that stands for the number of atoms of that element in a molecule. If there is only one atom for that element, no number follows the symbol. Ex. H_2O

Ionic Bonding

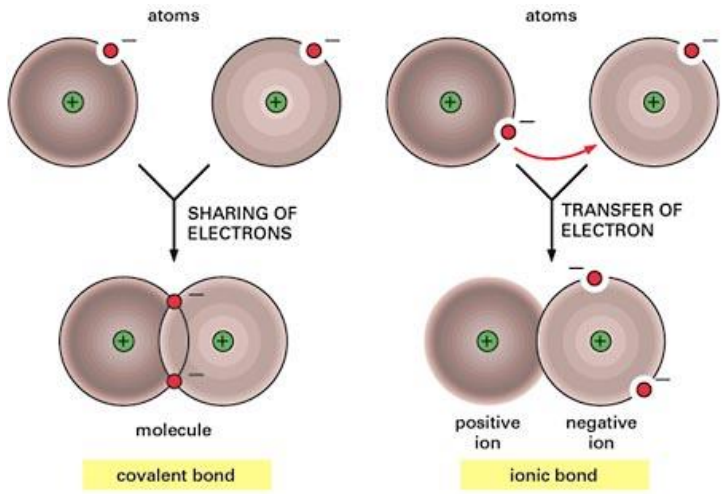


Protons +11	Protons +17	Protons +11	Protons +17
Electrons -11	Electrons -17	Electrons -10	Electrons -18
Charge 0	Charge 0	Charge +1	Charge -1

Oxidation/Reduction

- **Oxidation** refers to the loss of electrons
- **Reduction** refers to the gain of electrons
- Ex. Na+ Cl ➡ $Na^+ Cl^-$
  - The sodium has been oxidized and the chlorine has been reduced

Ionic and covalent bonds



Chemical reactions

- **Chemical reactions** are often indicated by writing a chemical equation.
- Equations must be balanced, i.e. you must have an equal number of atoms for each element on each side of the equation because the same amount of matter is present before and after the reaction.
- The atoms or molecules to the left of an arrow are the **reactants**- the substances that react with one another to give a product(s)
- The **products** are placed to the right of the arrow.

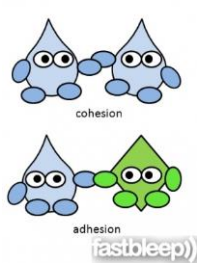
QUESTION AND ANSWER

Describe the 2 main types of chemical bonds.

How does the structure of water contribute to its unique properties?

Special properties of water

1. Water expands slightly upon freezing making ice less dense than liquid water (hence why it floats)
2. Polar
3. Cohesion
4. Adhesion
5. High heat capacity
6. Water is a solvent- can dissolve many substances (due to hydrogen bonding)



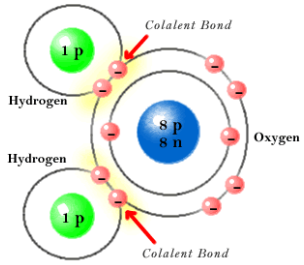
Properties of water

- The water molecule is neutral (10 protons and 10 electrons)
- A water molecule is **polar** because there is an uneven distribution of electrons between the oxygen and hydrogen atoms
  - **Polar bonds** are formed when atoms in a covalent bond do not share electrons equally
  - Polar molecules can attract each other and thus water is held together by hydrogen bonds- which aids in its special properties.

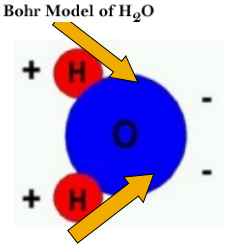
Properties of Water

Polar Molecule

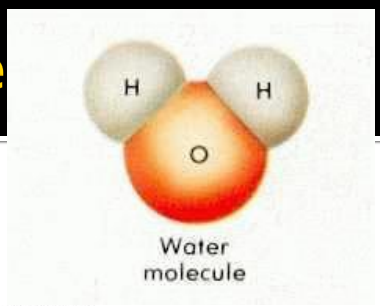
- Water has covalent bonds
- Water is a polar molecule- Unequal sharing of electrons.
- Oxygen "pulls" harder on negative electrons than H—gives O slight negative charge.
- **Water has polar, covalent bonds



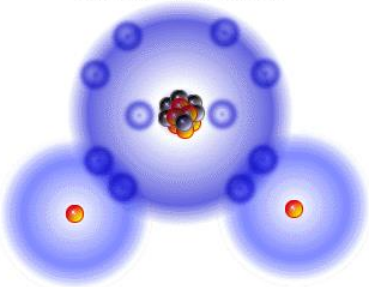
Bohr Model of H_2O

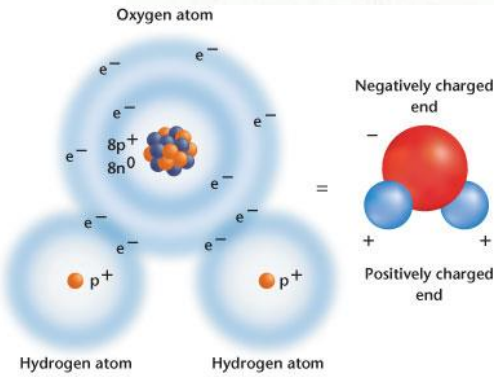


The water molecule



Water Molecule

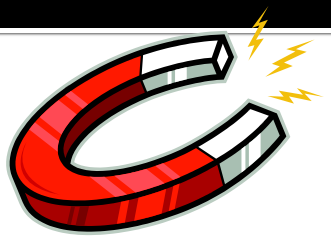


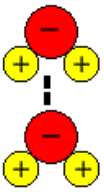


Properties of Water

Hydrogen Bonds

- Polarity causes water molecules to attract each other like magnets
- H (+) attracts O (-) forming a hydrogen bond
- Gives water special properties due to multiple hydrogen bonds formed
- Hydrogen bonds are not as strong as covalent or ionic bonds

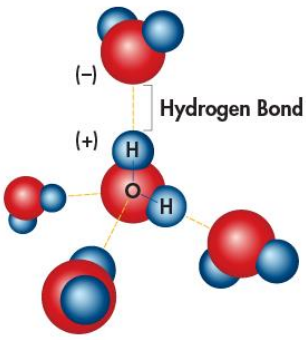




Hydrogen Bond

Hydrogen Bonding

- Because of their partial positive and negative charges, polar molecules such as water can attract each other.
- The attraction between a hydrogen atom on one water molecule and the oxygen atom on another is known as a **hydrogen bond.**
- Water is able to form multiple hydrogen bonds, which account for many of its special properties.
- Hydrogen bonds are not as strong as covalent or ionic bonds, and they can form in other compounds besides water.

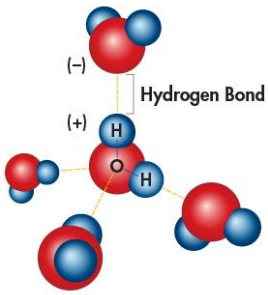


Water (con't)

- **Cohesion** is an attraction between molecules of the same substance due to hydrogen bonding.
  - This is why molecules on the surface of water are drawn inward- hence beads of water.
  - Cohesion also produces surface tension- explains insects walking on water
- **Adhesion** is an attraction between molecules of different substances.
  - Ex. Capillary action
- **Heat Capacity**
  - Multiple hydrogen bonds between water molecules results in more heat energy needed to raise the temperature of water. Thus water's heat capacity is relatively high.

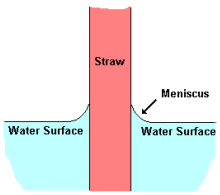
Cohesion

- **Cohesion** is an attraction between molecules of the same substance.
- Because a single water molecule may be involved in as many as four hydrogen bonds at the same time, water is extremely cohesive.
- Cohesion causes water molecules to be drawn together, which is why drops of water form beads on a smooth surface.
- Cohesion also produces surface tension, explaining why some insects and spiders can walk on a pond's surface.



Adhesion

- **Adhesion** is an attraction between molecules of different substances.
- The surface of water in a graduated cylinder dips slightly in the center, forming a curve called a meniscus, because the adhesion between water molecules and glass molecules is stronger than the cohesion between water molecules.
- Adhesion between water and glass also causes water to rise in a narrow tube against the force of gravity. This effect is called capillary action.
- Capillary action is one of the forces that draws water out of the roots of a plant and up into its stems and leaves.
- Cohesion holds the column of water together as it rises.

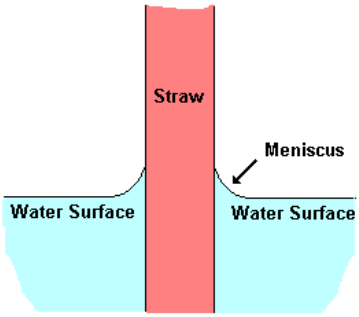


Heat Capacity

- Because of the multiple hydrogen bonds between water molecules, it takes a large amount of heat energy to cause those molecules to move faster and raise the temperature of the water.
- Water's heat capacity, the amount of heat energy required to increase its temperature, is relatively high.
- Large bodies of water, such as oceans and lakes, can absorb large amounts of heat with only small changes in temperature. This protects organisms living within from drastic changes in temperature.
- At the cellular level, water absorbs the heat produced by cell processes, regulating the temperature of the cell.

Properties of Water
Cohesion and Adhesion

- **Cohesion**—attraction between molecules of the same substance
  - Water molecules stick together
- **Adhesion**-attraction between molecules of different substances
  - Water attracted to molecules in glass and plastic



Solutions and suspensions

- Water's polarity gives it the ability to dissolve both ionic compounds and other polar molecules.
- **A mixture** is a material composed of 2 or more elements or compounds that are physically mixed together but not chemically combined. Ex. Salt and pepper
- **A solution** contains evenly distributed components.
  - **Solute** is the substance that is dissolved, ex. salt
  - **Solvent** is the substance in which the solute dissolves, ex. Water
- **Suspensions** are mixtures of water and non-dissolved material. Ex. Water and oil, blood

Properties of Water
Solutions

- Occurs when one substance is dissolved in another.
- A solute gets dissolved
- A solvent does the dissolving.

QUESTION AND ANSWER

How does the structure of water contribute to its unique properties?

Explain what makes a solution acidic and basic

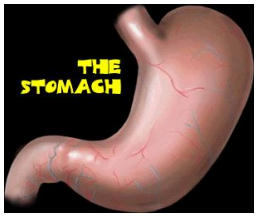
Acids, bases, pH

- **pH scale** is used to indicate the concentration of hydrogen ions (H^+) in solution
  - Ranges from 0 to 14
  - At 7: the concentration of H^+ ions and OH^- ions is equal
  - Solutions below a pH of 7 are acidic because they have more H^+ ions than OH^- ions. The lower the pH, the greater the acidity
  - Solutions with a pH above 7 are called basic because they have more OH^- ions than H^+ ions. The higher the pH, the more basic the solution.

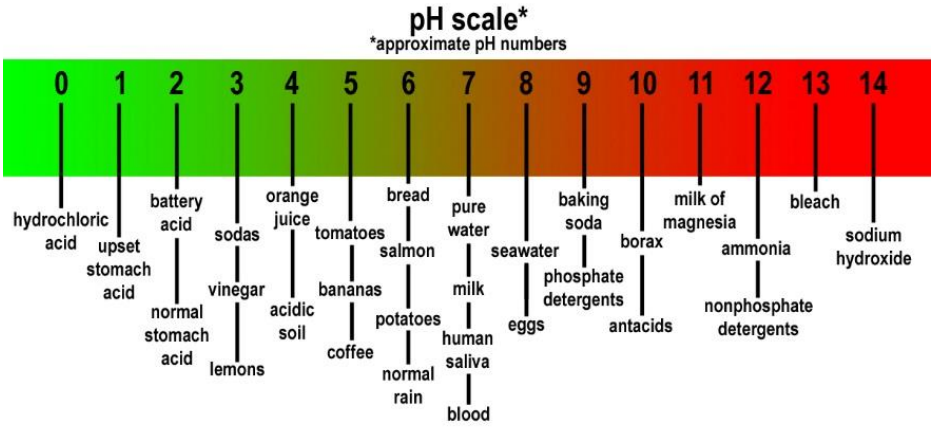
Properties of Water
Acids, Bases, and pH

- pH scale
  - pH scale from 0-14
    - Pure water= neutral: pH7
    - Acids: HCl, H_2SO_4
      - <7 acidic
      - High H+ concentration; low pH
    - Bases
      - >7 basic
      - Low H+ concentration; high OH- concentration ; high pH

        H+ + OH- → H_2O



pH scale

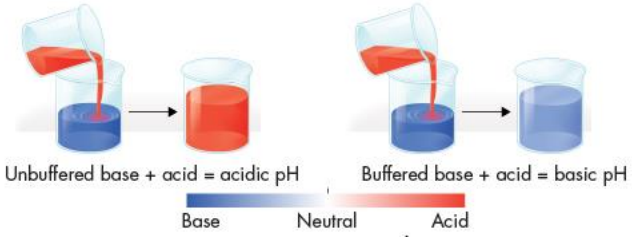


Acids, bases, buffers

- **Acid** is any compound that forms H^+ ions in solution
  - Strong acids have pH values between 1-3
- **A base** is a compound that produces hydroxide ions (OH^- ions) in solution.
  - Strong bases have pH values between 11-14
- **Buffers** are weak acids or bases that can react with strong acids or bases to prevent sharp, sudden changes in pH.
  - Helps to maintain homeostasis

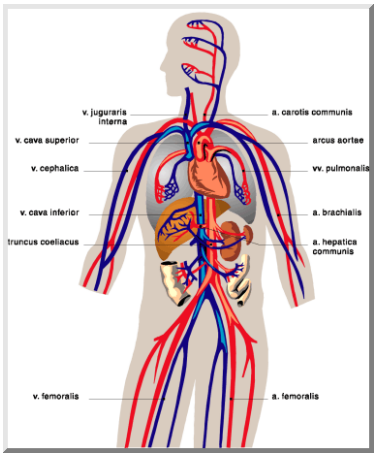
Buffers

- Adding acid to an unbuffered solution causes the pH of the unbuffered solution to drop. If the solution contains a buffer, however, adding the acid will cause only a slight change in pH.



Properties of Water
Buffers

- Homeostasis→ human blood must be between pH 6.7-7.5
- Body uses buffers
  - Weak acids or bases
  - Prevent sharp changes in pH



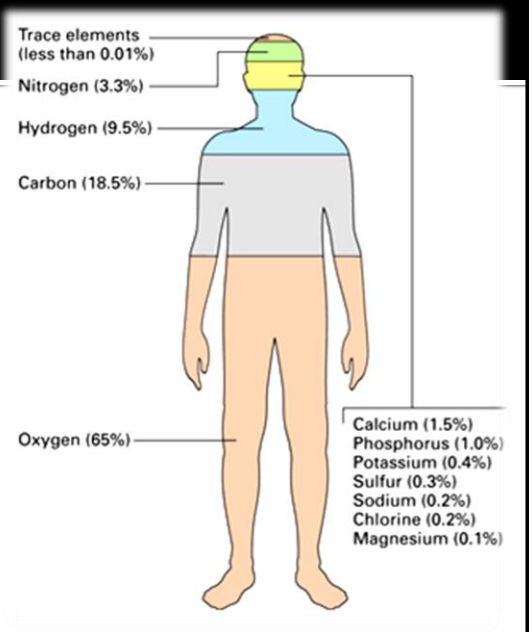
QUESTION AND ANSWER

Explain what makes a solution acidic and basic

Describe the structure and function of each of the four groups of macromolecules

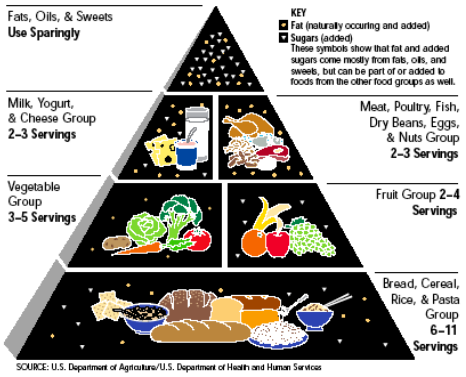
Elements of Life

- 96% of living organisms is made of:
  - carbon (C)
  - oxygen (O)
  - hydrogen (H)
  - nitrogen (N)



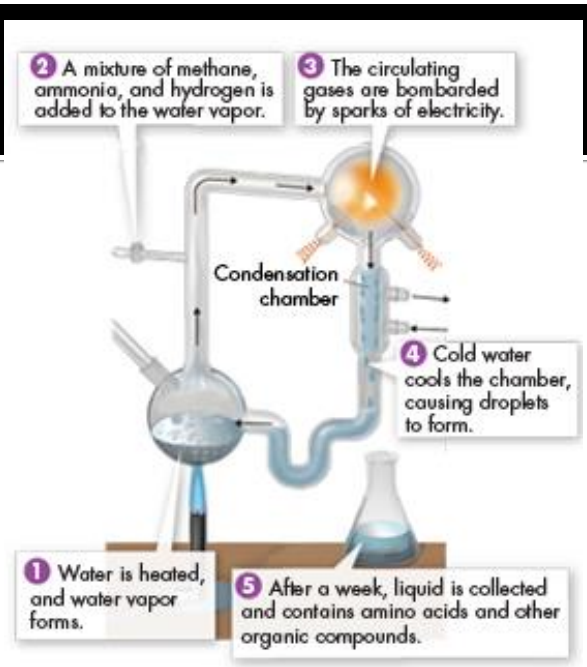
What do we need to eat?

- Foods to give you more building blocks & more energy
  - for building & running bodies
  - carbohydrates
  - proteins
  - fats
  - nucleic acids
  - vitamins
  - minerals, salts
  - water



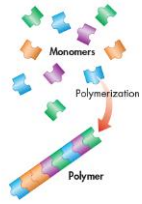
Earth's Early History

- Earth is 4.6 billion years old
- Earth's early atmosphere probably contained hydrogen cyanide, carbon dioxide, carbon monoxide, nitrogen, hydrogen sulfide, and water vapor
  - Earth's early atmosphere contained little to no oxygen
- Miller and Urey simulated the conditions on Earth in a lab setting
  - They filled a flask with hydrogen, methane, ammonia, and water and passed electric sparks to simulate lightning
  - Over a few days amino acids were formed
  - Miller and Urey's experiments suggested how mixtures of the organic compounds necessary for life could have arisen from simpler compounds present on a primitive Earth


2 A mixture of methane, ammonia, and hydrogen is added to the water vapor.
3 The circulating gases are bombarded by sparks of electricity.
Condensation chamber
4 Cold water cools the chamber, causing droplets to form.
1 Water is heated, and water vapor forms.
5 After a week, liquid is collected and contains amino acids and other organic compounds.

2.3: Carbon compounds

- Macromolecules or "giant molecules" are made of thousands of smaller molecules
  - Formed from the process of polymerization in which smaller units, **monomers,** join together to form **polymers**
    - **Dehydration synthesis or polymerization-** a chemical reaction in which two or more molecules bond by losing one or more water molecules.
    - **Hydrolysis-** a chemical reaction in which the interaction of water and a compound result in the breaking up of that compound.
- Four groups of organic compounds/biomolecules found in living things are:
  1. Carbohydrates
  2. Lipids
  3. Nucleic acids
  4. Proteins



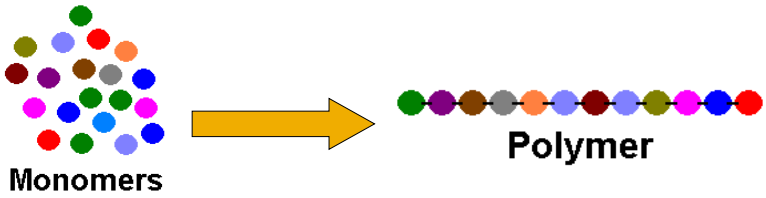
Carbon Compounds
Organic Macromolecules

- Many in living cells

Organic Macromolecules

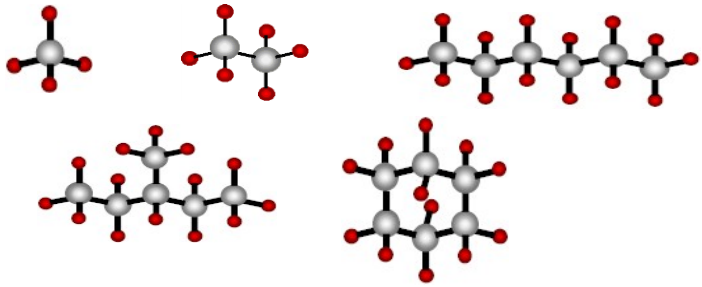
has C-C bonds large molecules

- Formed by polymerization or dehydration synthesis



Building large molecules of life

- Chain together smaller molecules
  - building block molecules = monomers

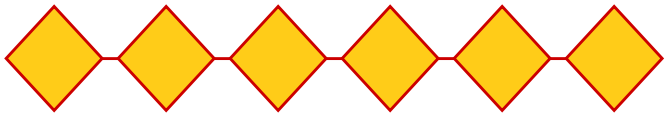


- Big molecules built from little molecules
  - polymers

Building large organic molecules

- Small molecules = building blocks = monomers

- Bond them together through dehydration synthesis= polymers



Building important polymers

Carbohydrates = built from sugars

sugar – sugar – sugar – sugar – sugar – sugar

Proteins = built from amino acids

amino acid – amino acid – amino acid – amino acid – amino acid – amino acid

Nucleic acids (DNA) = built from nucleotides

nucleotide – nucleotide – nucleotide – nucleotide

1. Carbohydrates






1. Carbohydrates

- Carbohydrates are compounds made up of carbon, hydrogen, and oxygen atoms, usually in a 1:2:1 ratio, ex. $C_6H_{12}O_6$
- This is the main source of energy for living things as well as used for structural purposes (cell wall) in plants (cellulose) and fungi and insects (chitin)
- Simple sugars or **monosaccharides**, ex. Glucose, galactose, fructose
- **Disaccharides** such as sucrose, maltose, and lactose
- Complex sugars or **polysaccharides**, ex. Plant starches, glycogen, cellulose, chitin
- Synthesized during photosynthesis in the chloroplast and broken down in cellular respiration in the mitochondria to release energy

Organic Compounds
Carbohydrates

- Subunit = sugars= saccharides
  - C, H and O in 1:2:1 ratio (i.e. $C_6H_{12}O_6$)
  - Carbs are either
    - Sugars = monosaccharides
      - sucrose, glucose, fructose
  - Starches = polysaccharides
    - sugars hooked together
    - pasta, cellulose (plant cell walls)
    - Chitin (cell wall of fungi and exoskeleton of insects)
    - Glycogen- short term storage of glucose in the liver and muscle cells

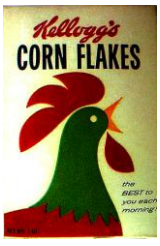
Organic Compounds
Carbohydrate Function

- Function
  - Main source of energy for living things
  - Converted to ATP—gasoline for cells
  - Monosaccharides = immediate energy
  - Polysaccharides = temporary stored energy
  - Plants store carbs as cellulose—gives their cells strength

Carbohydrates

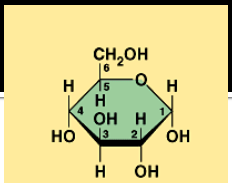
- Building block molecules = **sugars**

sugar - sugar - sugar - sugar - sugar



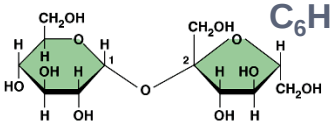
Carbohydrates

- Elements: C, H, O
- Function:
  - quick energy
  - energy storage
  - structure
    - cell wall in plants
    - cell wall in fungi made of chitin
    - exoskeleton made of chitin in insects
- Examples
  - sugars
  - starches
  - cellulose (cell wall of plants)
  - glycogen



glucose

$C_6H_{12}O_6$

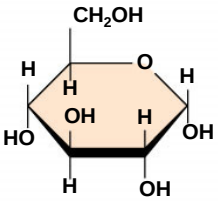


sucrose

starch

Sugars = building blocks

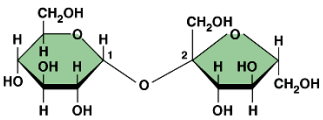
- Names for sugars usually end in ***-ose***
  - glucose
  - fructose
  - sucrose
  - maltose



glucose

$C_6H_{12}O_6$

fructose



sucrose

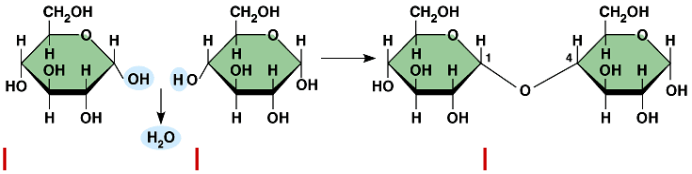
maltose

Building carbohydrates

- Product of dehydration synthesis

1 sugar = monosaccharide

2 sugars = disaccharide



glucose + glucose → maltose

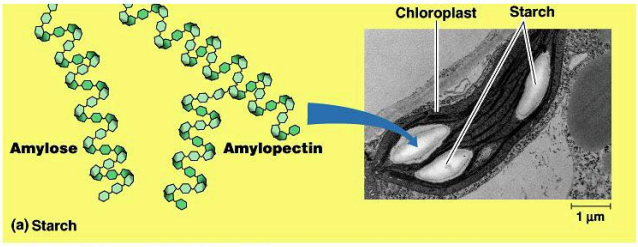
Building BIG carbohydrates

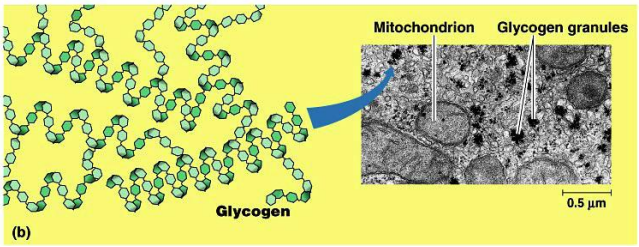
glucose + glucose + glucose… = polysaccharide

starch (plant)

energy storage

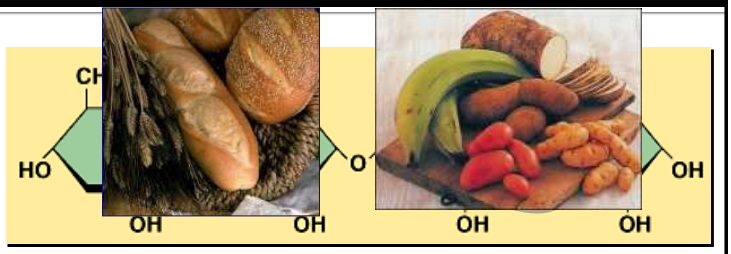
glycogen (animal)





Digesting starch vs. cellulose

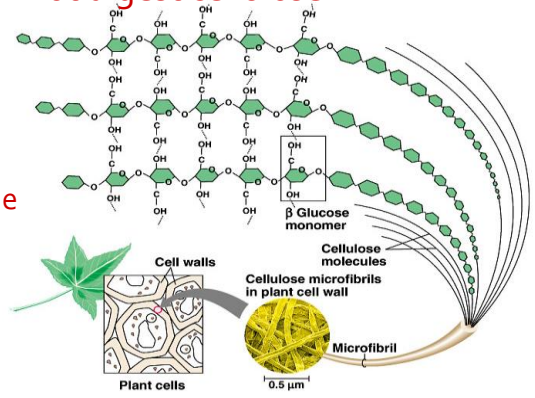
starch
easy to digest

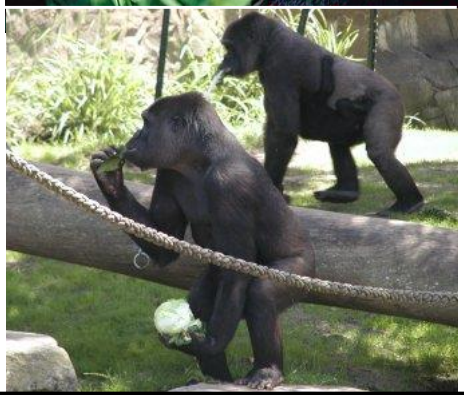


cellulose
hard to digest

Cellulose

- Cell walls in plants
  - herbivores can digest cellulose well
  - most carnivores cannot digest cellulose
    - that's why they eat meat to get their energy & nutrients
    - cellulose = roughage
      - stays undigested
      - keeps material moving in your intestines





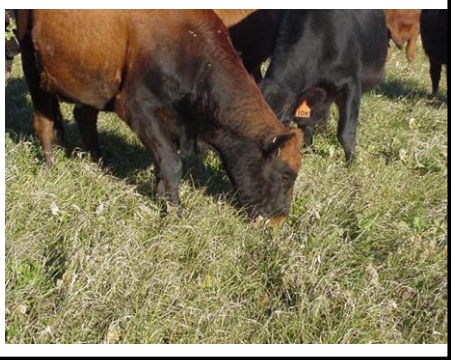
Different Diets of Herbivores

Cow

- can digest cellulose well; no need to eat other sugars

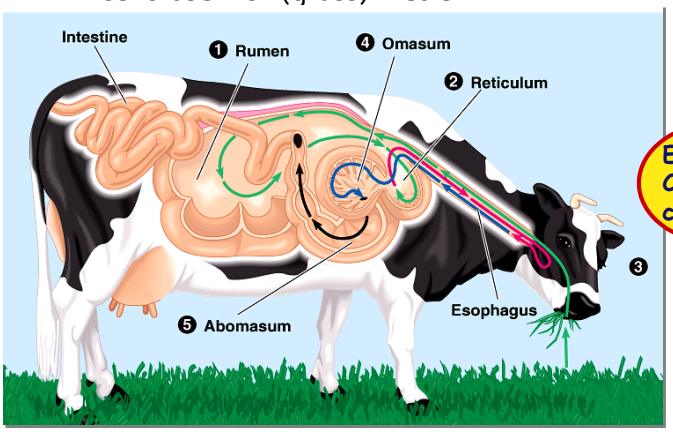
Gorilla

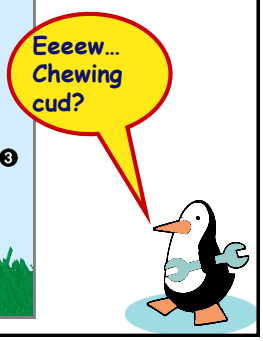
- can't digest cellulose well; must add another sugar source, like fruit to diet



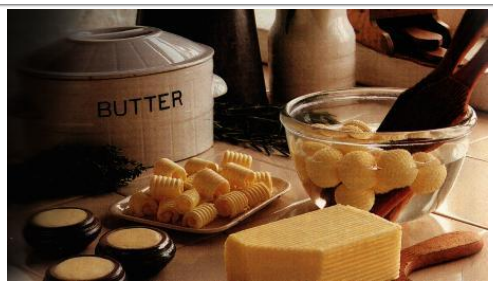
Helpful bacteria

- How can cows digest cellulose so well?
  - BACTERIA live in their stomachs & help digest cellulose-rich (grass) meals





2. Lipids: Fats & Oils



2. Lipids

- Made from carbon, oxygen, and hydrogen atoms (and phosphorus if a phospholipid)
  - Not soluble in water
  - Ex. Fats, oils, waxes, steroids
- Used to store energy, hormones (such as steroids), and are a part of biological membranes and waterproof coverings
- Synthesized at the smooth endoplasmic reticulum (SER)
- Formed when fatty acids attach to glycerol molecules (there is no true monomer)
- Contains a **hydrophobic/non-polar** or water- hating part as well as a **hydrophilic/ polar** or water-loving part
- Examples
  - phospholipid- 2 fatty acids and glycerol or
  - triglycerides – 3 fatty acids and glycerol

Organic Compounds
Lipids

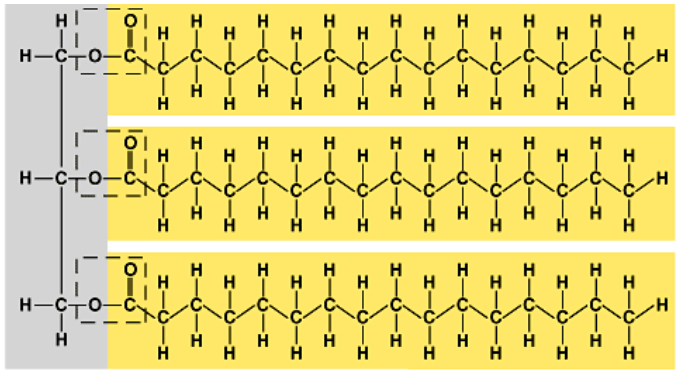
- Subunit = fatty acids and glycerol
- Structure
  - C, H, and O
  - Lipids-Fats, oils, waxes
  - Saturated and Unsaturated fats
  - Hydrophobic—"water-fearing"-not dissolvable in water

Organic Compounds
Lipid Function

- Function
  - Store energy for use later
  - Hormones, ex. Steroids and testosterone
  - Cell membranes
  - Waterproof covering (skin)

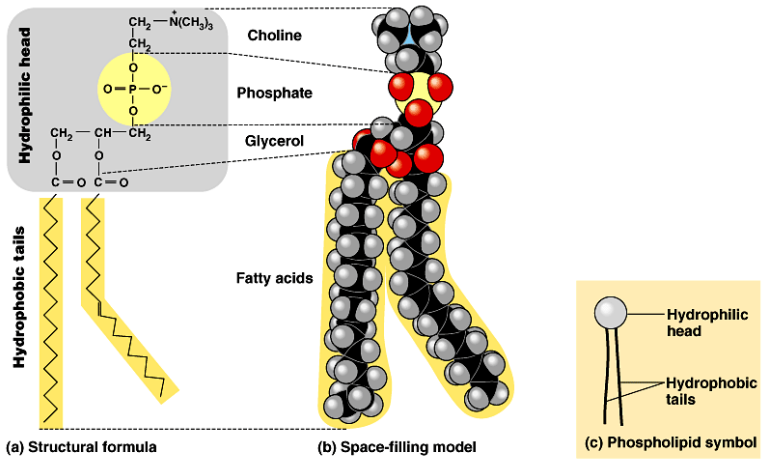
Triglycerids

not a chain (polymer) = just a "big fat molecule"



(b) Fat molecule

Phospholipid Molecule



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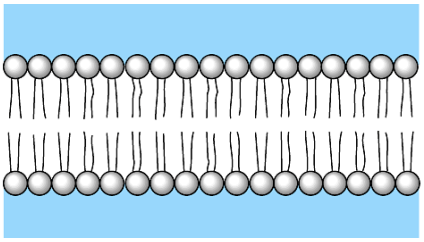
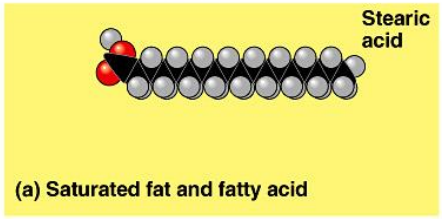
Phospholipids

- Cell membranes are made out of lipids
  - phospholipids
  - heads are on the outside touching water
    - "like" water (hydrophilic) / polar
  - tails are on inside away from water
    - "scared" of water (hydrophobic)/ non-polar
  - forms a barrier between the cell & the outside



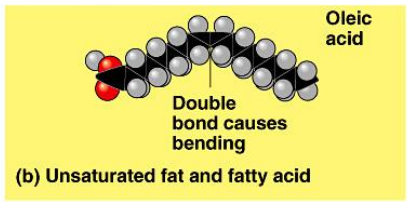
Saturated fats

- Has the maximum possible number of hydrogen atoms attached to every carbon atom.
  - All of the carbons are attached to each other with single bonds.
- Most animal fats
  - solid at room temperature
- Limit the amount in your diet
  - contributes to heart disease
  - deposits in arteries



Unsaturated fats

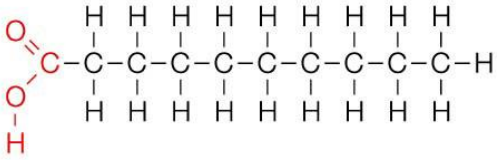
- A fat in which at least one double bond within the fatty acid chain exists
  - Monounsaturated- one double bond
  - Polyunsaturated- more than one double bond
- Plant, vegetable, & fish fats
  - liquid at room temperature
    - the fat molecules don't stack tightly together
- Better choice in your diet



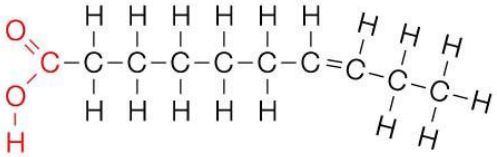
(b) Unsaturated fat and fatty acid

Saturated vs. unsaturated fatty acids

Saturated

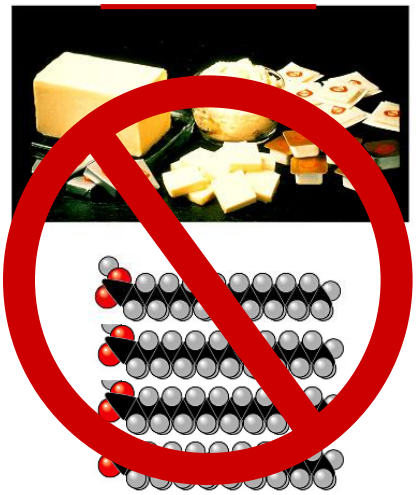


Unsaturated

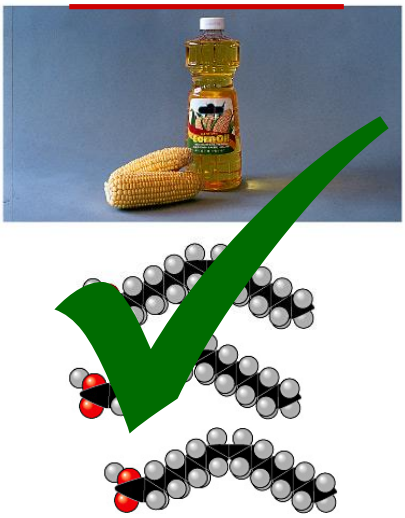


Saturated vs. unsaturated

saturated

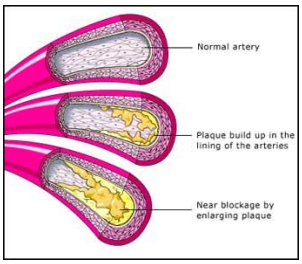


unsaturated



Other lipids in biology

- Cholesterol
  - good molecule in cell membranes
  - make hormones from it
    - including sex hormones
  - but too much cholesterol in blood may lead to



4. Proteins






4. Proteins

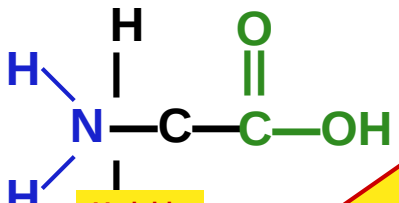
- Contain nitrogen, carbon, hydrogen, and oxygen
- Is made up of **amino acids** (which consist of an amino group, carboxyl group, and a variable R group)
  - More than 20 amino acids exist
- Synthesized at ribosomes
- Some proteins control the rate of reaction and regulate cell processes. Others transport substances into or out of cells or help fight disease
- Has a specific shape that can **denature** or change when exposed to dangerously high temperatures

Proteins

- Building block = **amino acids**

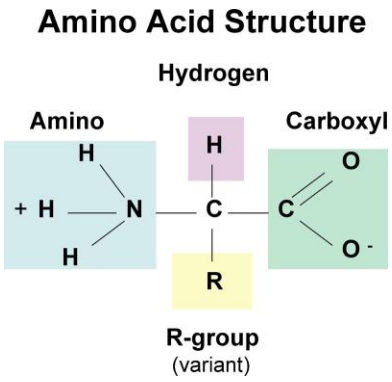
amino acid – amino acid – amino acid – amino acid – amino acid

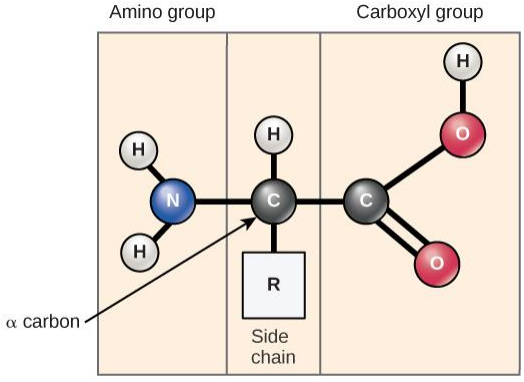
- **20 different amino acids**



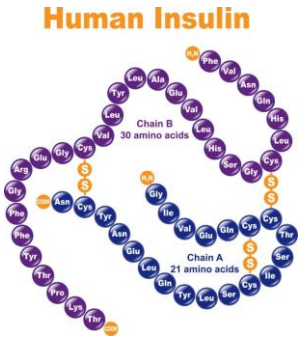
There's 20 of us… like 20 different letters in an alphabet! *Can make lots of different words*

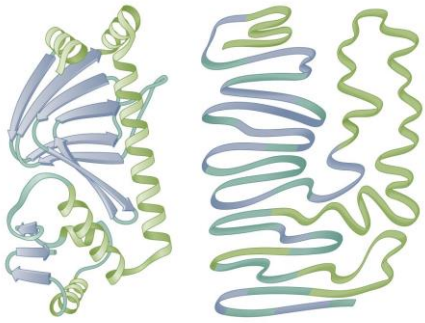
Amino Acid Structure





Protein Structure



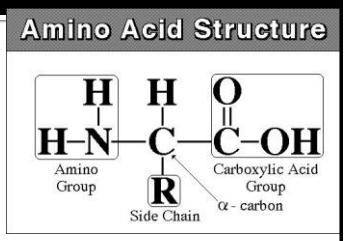


Organic Compounds
Protein Function

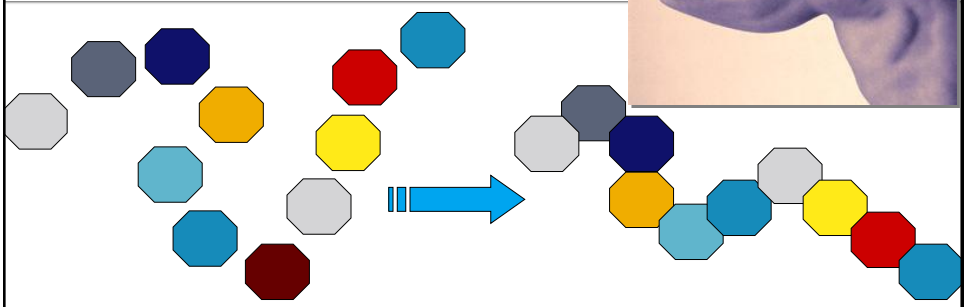
- Function
  - Enzymes → proteins that control chemical reactions
  - Form bones and muscles
  - Forms hair and nails (keratin)
  - Part of cell membrane
  - PROTEINS ARE **NOT** SOURCES OF ENERGY!

Organic Compounds
Protein Structure

- Subunit = amino acids
- Amino acids held together by peptide bonds
- A chain of amino acids are called **polypeptides**
- Structure
  - C, H, O, N,
  - 20 different amino acids form 1000's of different proteins



Example of synthesis



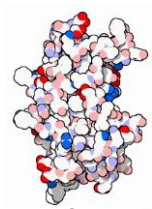
amino acids **protein**

- **Proteins are synthesized by bonding amino acids**

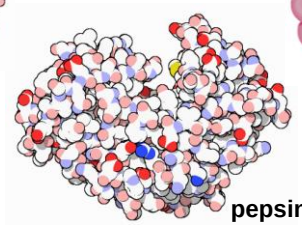
amino acids = building block
protein = polymer

For proteins: SHAPE matters!

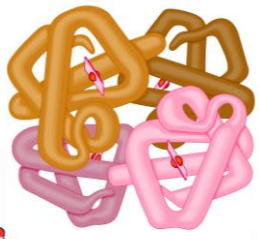
- Proteins fold & twist into 3-D shape
  - that's what happens in the cell!
- Different shapes = different jobs



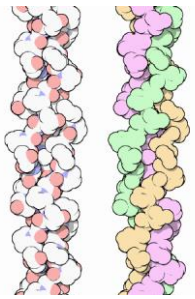
growth hormone



pepsin



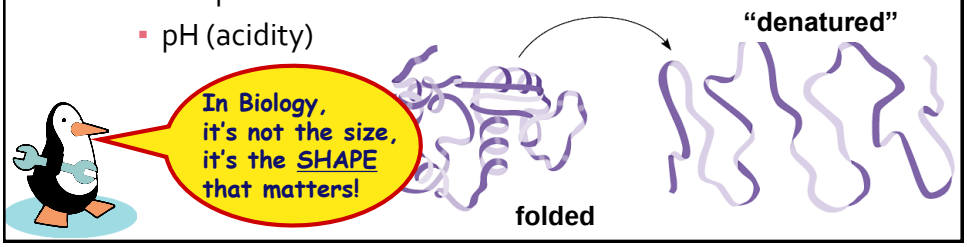
hemoglobin



collagen

It's SHAPE that matters!

- **Proteins do their jobs, because of their shape**
- Unfolding a protein destroys its shape
  - wrong shape = can't do its job
  - unfolding proteins = "denature"
    - temperature
    - pH (acidity)

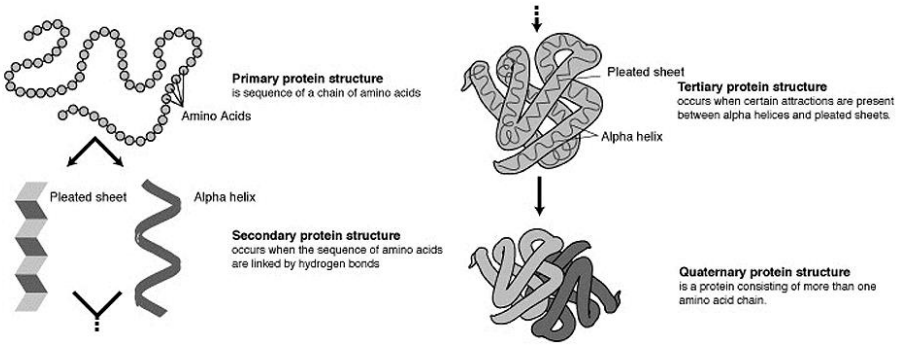


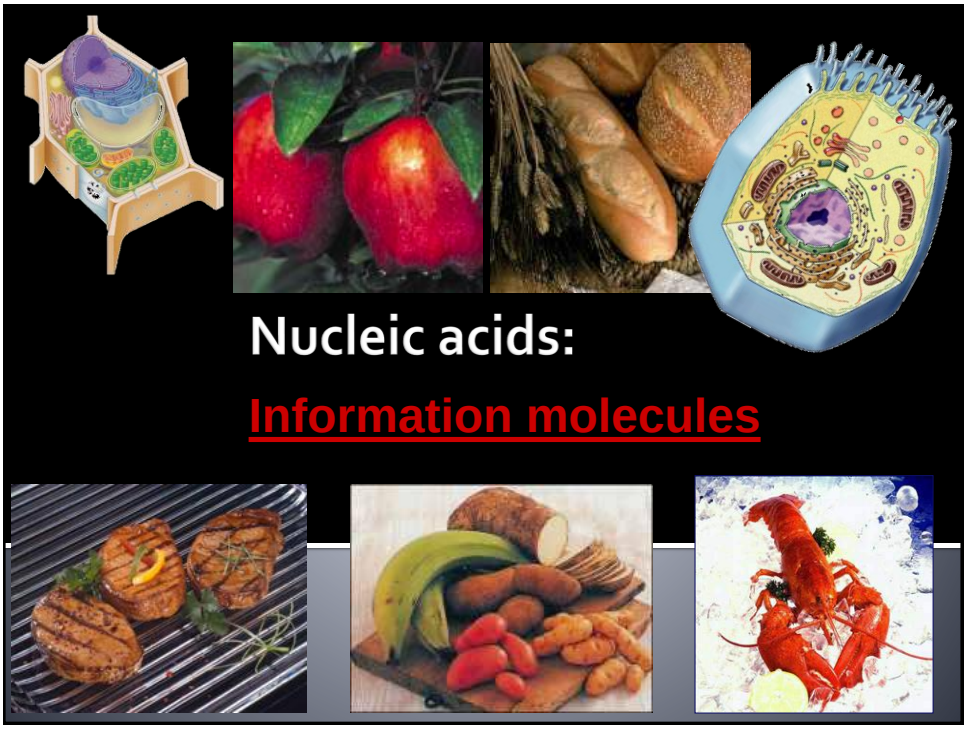
Protein Structures

- **The four protein structures are:**

1. **Primary**
   - Describes the unique order of the amino acids joined together to make the protein
2. **Secondary**
   - Refers to the coiling and folding of a polypeptide chain that gives the protein its 3-D shape
   - Examples: alpha (α) helix and beta (β) pleated sheet
3. **Tertiary**
   - Comprehensive 3-D structure of the polypeptide
4. **Quaternary**
   - Refers to the structure of a protein macromolecule formed by interactions between multiple polypeptide chains

Protein Structures





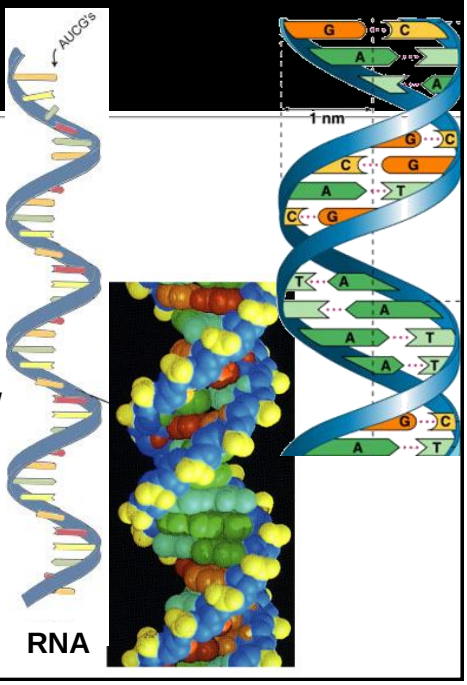
3. Nucleic acids

- Are macromolecules containing hydrogen, oxygen, nitrogen, carbon, and phosphorus
- Consists of polymers of **nucleotides** that consists of 3 parts:
  - a 5 carbon sugar,
  - phosphate group, and a
  - nitrogenous base (held together by hydrogen bonds)
- Nucleotides are joined by covalent/phosphodiester bonds to form **nucleic acids**
- Nucleic acids store and transmit hereditary or genetic information and code for the production of proteins
- There are 2 kinds:
  - 1. Ribonucleic acids (RNA) and
  - 2. deoxyribonucleic acid (DNA)

Nucleic Acids

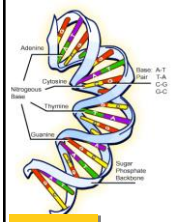
Examples

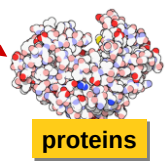
- DNA
  - DeoxyriboNucleic Acid
  - Double stranded
  - If located in the cytoplasm, the organism is a **prokaryote**, and if it is located in a nucleus, it is an **eukaryote**
- RNA
  - RiboNucleic Acid
    - Single stranded

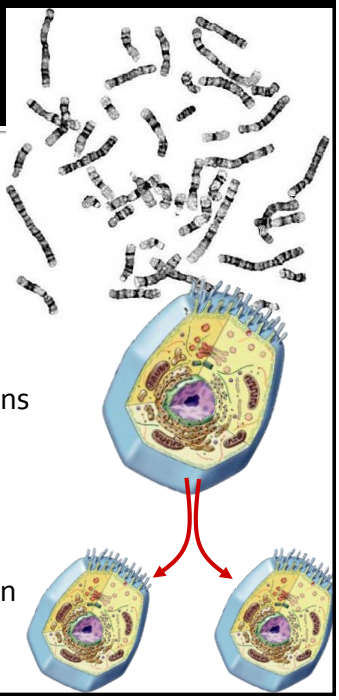


Nucleic Acids

- Function:
  - genetic material
    - stores information
      - genes
      - blueprint for building proteins
        - DNA → RNA → proteins
    - transfers information
      - blueprint for new cells
      - blueprint for next generation





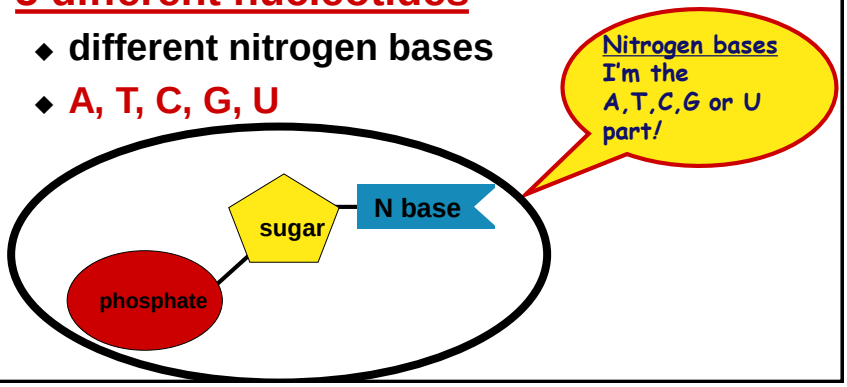


Nucleic acids

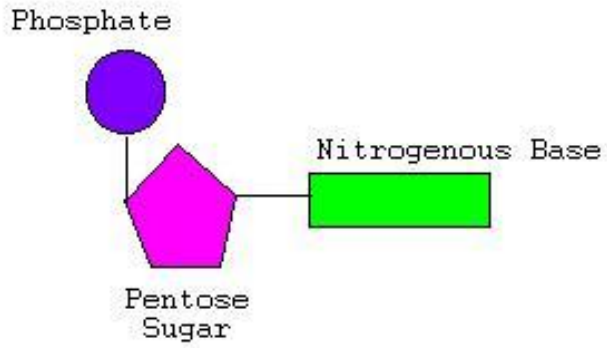
- Building block = **nucleotides**

nucleotide – nucleotide – nucleotide – nucleotide

- **5 different nucleotides**
  - **different nitrogen bases**
  - **A, T, C, G, U**

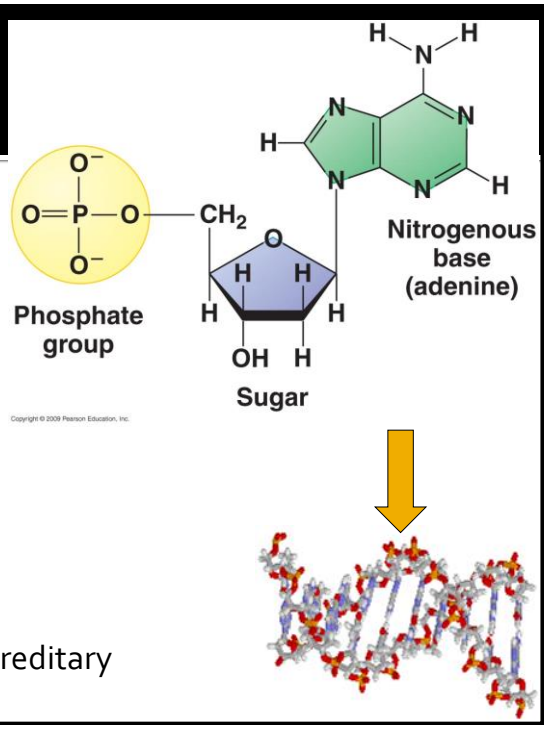


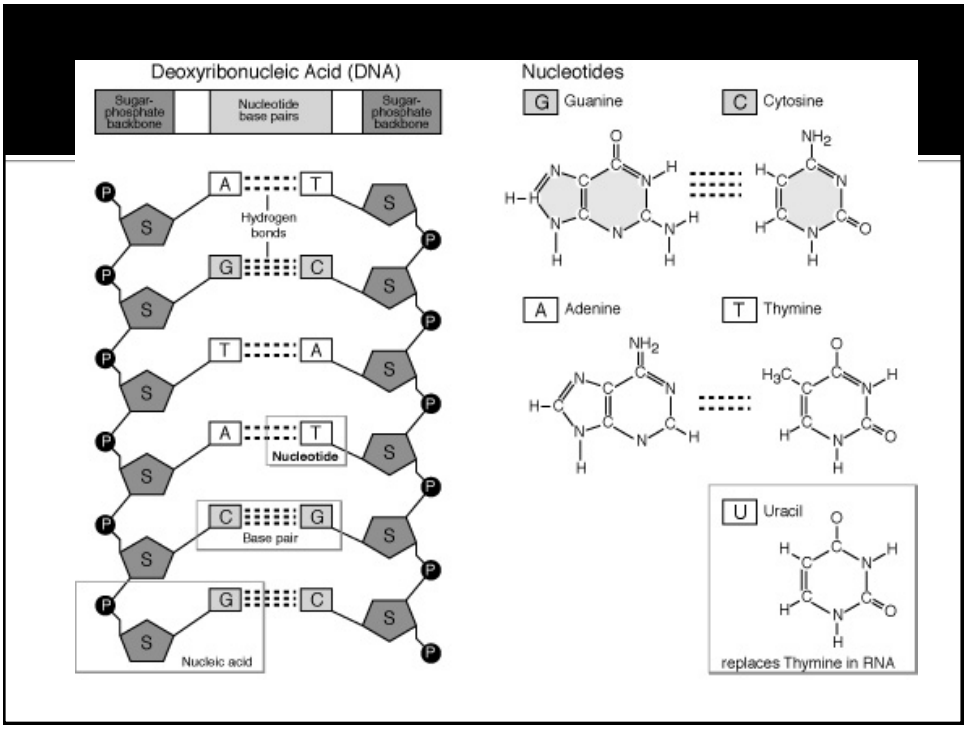
A nucleotide

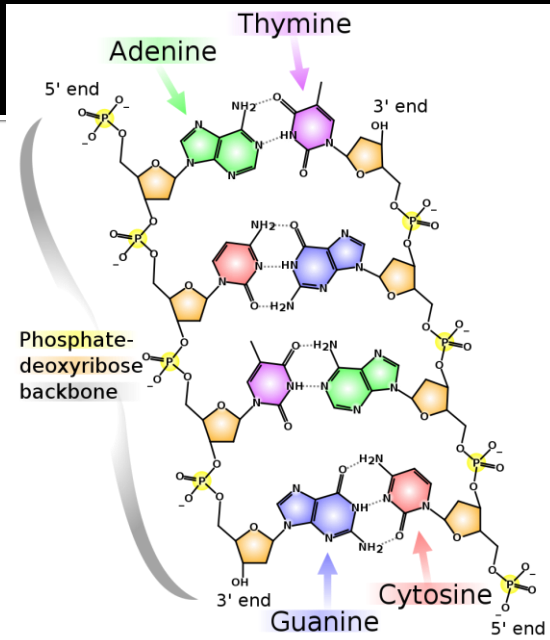


Nucleic Acids

- Subunit = nucleotides
- Structure
  - Nucleotides:
    - Phosphate group
    - 5 C sugar
      - DNA: deoxyribose,
      - RNA: ribose
    - Nitrogenous base
      - DNA: A, T, C, G
      - RNA: A, U, C, G
  - DNA and RNA
- Function
  - Store and transmit hereditary (genetic) info







QUESTION AND ANSWER

Describe the structure and function of each of the four groups of macromolecules

What role do enzymes play in living things and what affects their function?

Chemical reactions and enzymes

- **A chemical reaction** is a process that changes, or transforms, one set of chemicals into another
  - Mass or energy is conserved during chemical reactions
  - Always involves changes in the chemical bonds that join atoms in compounds
  - **Reactants** are the elements or compounds that enter into a chemical reaction
  - **Products** are the elements or compounds produced by a chemical reaction

Chemical reactions and enzymes (con't)

- Ex. $CO_2 + H_2O \Rightarrow H_2CO_3$
  Reactants Products
- Chemical reactions that release energy often occur spontaneously. Chemical reactions that absorb energy will not occur without a source of energy
- The energy that is needed to get a reaction started is the **activation energy**

Chemical Reactions and Enzymes
Chemical Reactions

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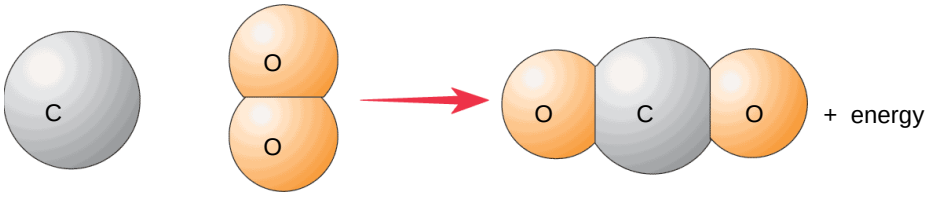
Reactant(s) → **Product(s)**

carbon + oxygen → carbon dioxide + energy

C + O_2 → CO_2 + energy



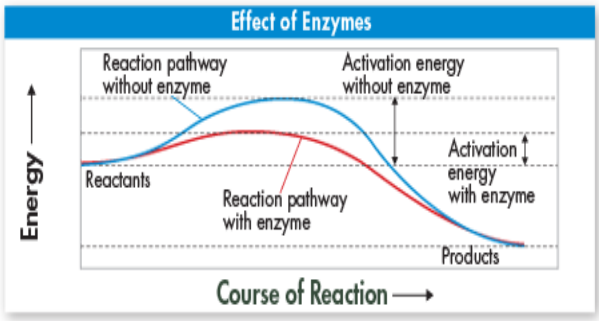
black solid *colorless gas* *colorless gas*

Enzymes

- A **catalyst** is a substance that speeds up the rate of chemical reaction.
  - Work by lowering a reaction's activation energy
- **Enzymes** are proteins that act as biological catalysts as they speed up chemical reactions that take place in cells
  - Are very specific- generally catalyzing only one chemical reaction and has a specific shape
  - Name usually ends in *–ase*, ex. Lactase, lipase, salivary amylase, carbonic anhydrase

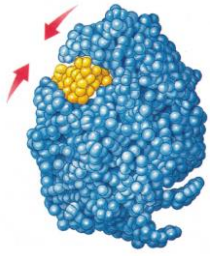
The Effect of Enzymes

- **Enzymes** are proteins that act as biological catalysts. They speed up chemical reactions that take place in cells.
- Enzymes act by lowering the activation energies, which has a dramatic effect on how quickly reactions are completed.

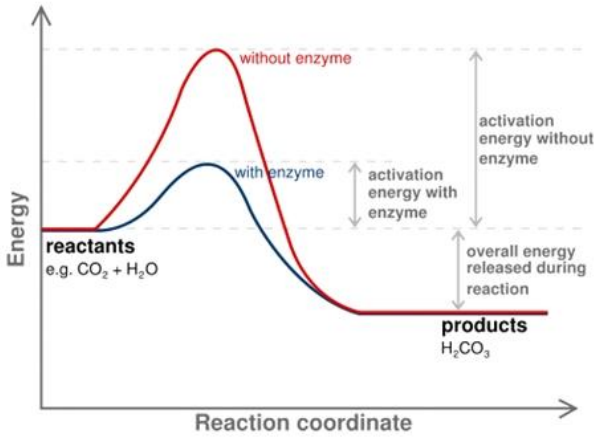


Enzymes are proteins

- **Each enzyme is the specific helper to a specific reaction**
  - each enzyme needs to be the right shape for the job
  - enzymes are named for the reaction they help
    - sucrase breaks down sucrose
    - proteases breakdown proteins
    - lipases breakdown lipids
    - DNA polymerase builds DNA



The action of enzymes

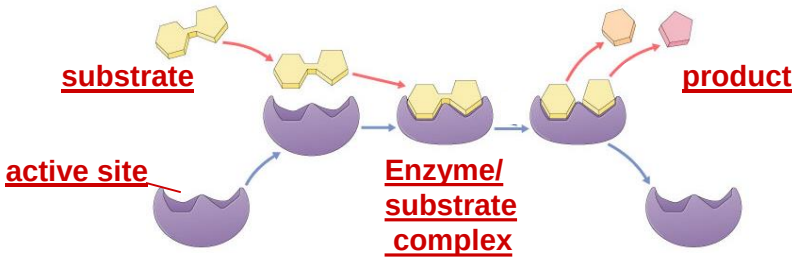


Enzyme action

- Enzymes provide a site where reactants can be brought together to react. These sites reduces the energy needed for a reaction.
- The reactants of enzyme-catalyzed reactions are known as **substrates**.
- The site where substrates bind are called **active sites**. When the substrates that have the same shape as the active site is attached to the active site, it forms **an enzyme-substrate complex** until the reaction is done, which the releases the products of the reaction

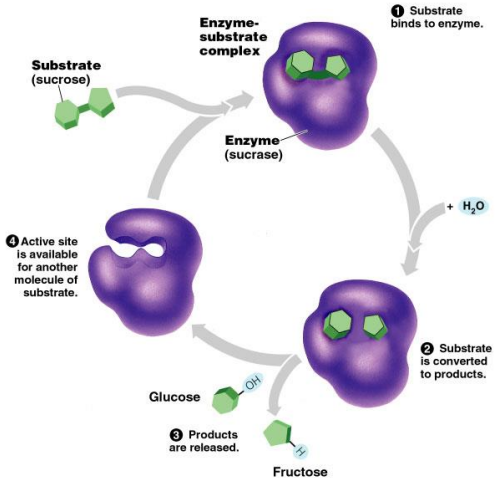
Enzymes aren't used up

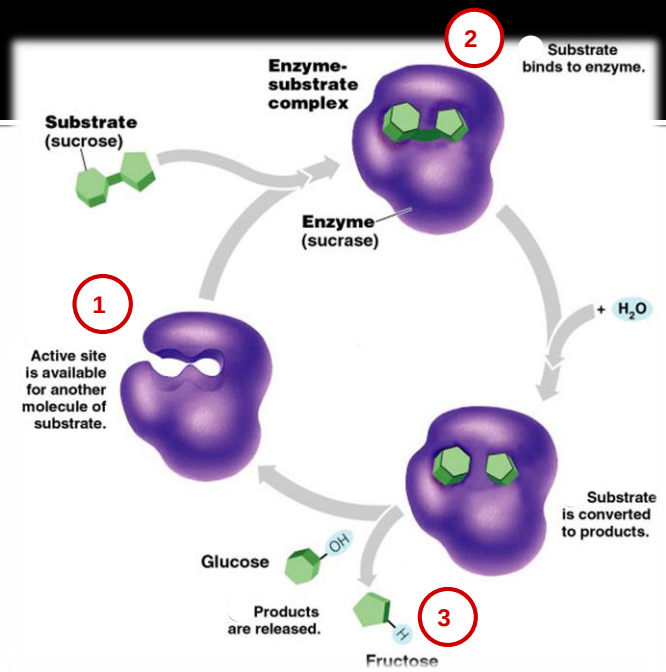
- Enzymes are not changed by the reaction
  - used only temporarily
  - re-used again for the same reaction with other molecules
  - very little enzyme needed to help in many reactions



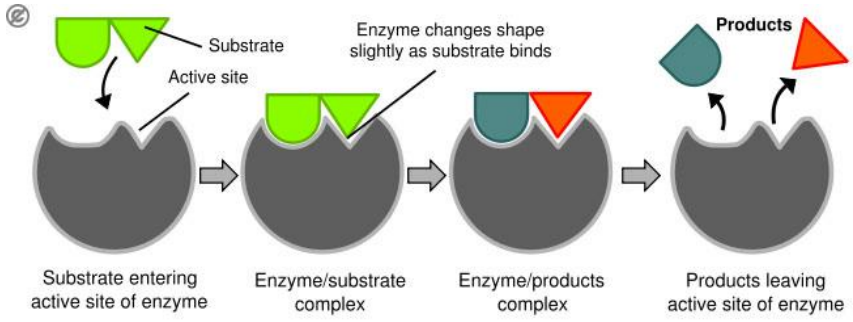
It's shape that matters!

- Lock & Key model
  - shape of protein allows enzyme & substrate to fit
  - specific enzyme for each specific reaction

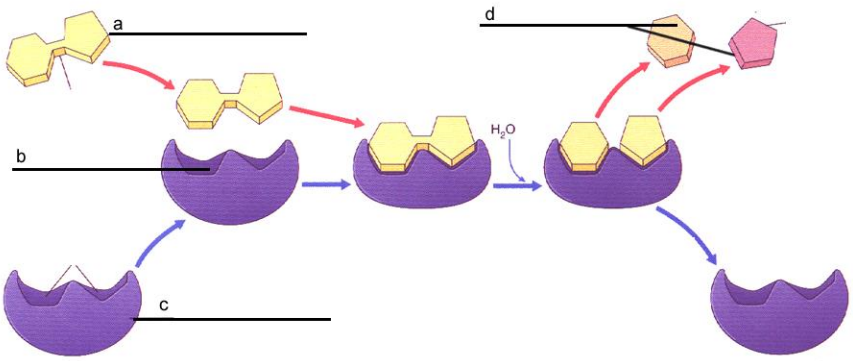




How enzymes work



Review of enzyme activity: Label



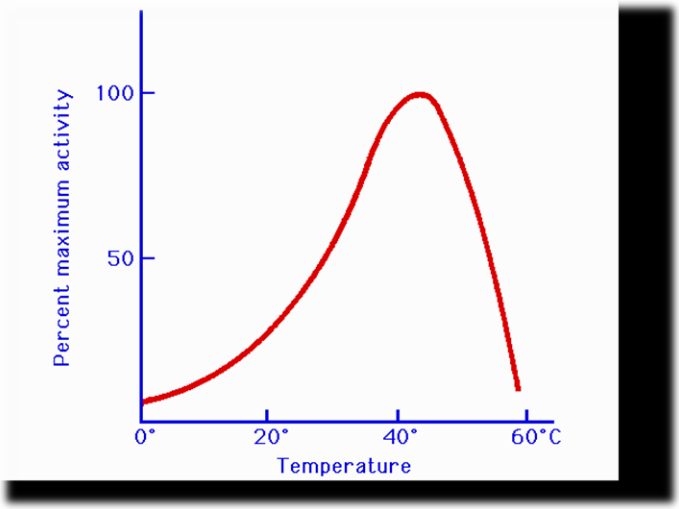
Regulation of enzyme activity

- Enzymes can be affected by the following variables:
  - 1. Temperature
  - 2. Substrate concentration
  - 3. pH

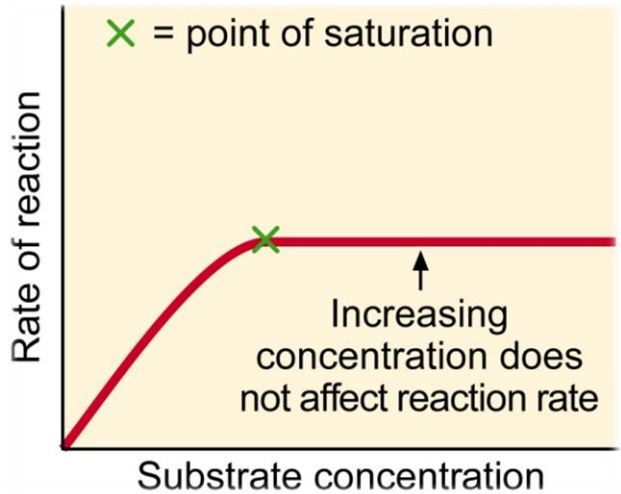
Temperature

- Effect on rates of enzyme activity
  - Optimum temperature
    - greatest number of collisions between enzyme & substrate
    - human enzymes
      - 35°- 40°C (body temp = 37°C)
  - Raise temperature (boiling)
    - denature protein = unfold = lose shape
  - Lower temperature T°
    - molecules move slower
    - fewer collisions between enzyme & substrate

1. Effect of temperature on enzyme activity



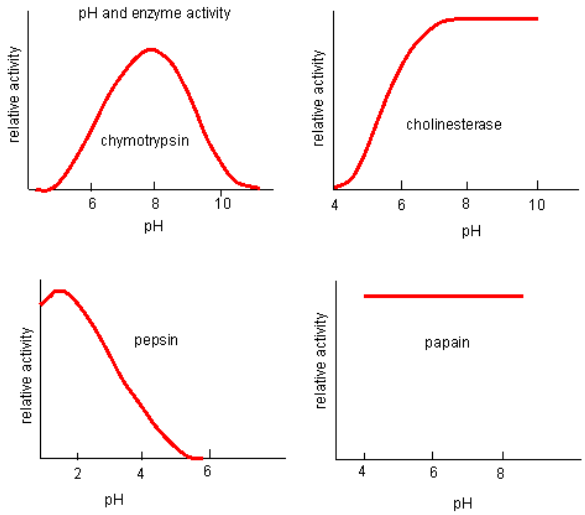
2. The effect of substrate concentration on enzyme activity



3. pH

- Effect on rates of enzyme activity
  - changes in pH changes protein shape (denature)
  - most human enzymes = pH 6-8
    - depends on where in body
    - pepsin (stomach) = pH 3
    - trypsin (small intestines) = pH 8

3. Various enzymatic activity in varying pH



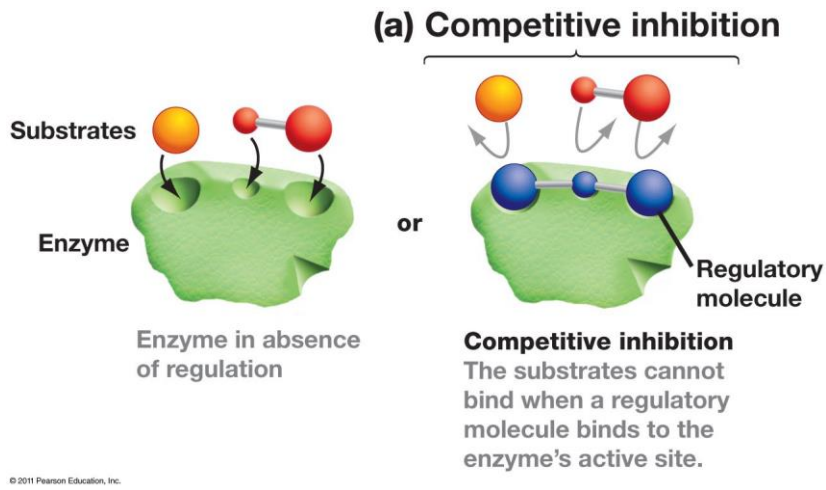
Inhibition

- Enzyme inhibitors are molecules that interact in some way with the enzyme to prevent it from working in the normal manner.
- Ex. poisons and drugs
- The 2 types of inhibition are:
  - 1. Competitive
  - 2. Non-competitive

Competitive Inhibition

- A competitive inhibitor is any compound which closely resembles the chemical structure and molecular geometry of the substrate.
- The inhibitor competes for the same active site as the substrate molecule. The inhibitor may interact with the enzyme at the active site, but no reaction takes place. The inhibitor is "stuck" on the enzyme and prevents any substrate molecules from reacting with the enzyme.
- However, a competitive inhibition is usually reversible if sufficient substrate molecules are available to ultimately displace the inhibitor. Therefore, the amount of enzyme inhibition depends upon the inhibitor concentration, substrate concentration, and the relative affinities of the inhibitor and substrate for the active site.

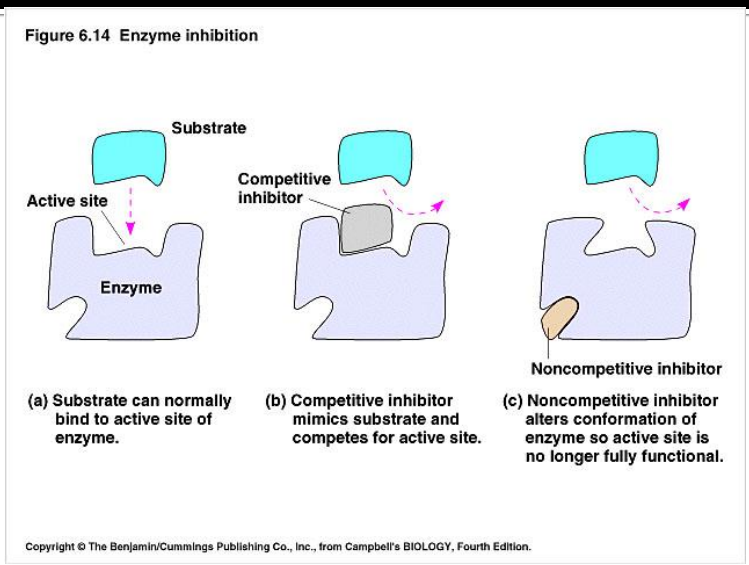
Competitive Inhibition



Non-competitive Inhibition

- A noncompetitive inhibitor is a substance that interacts with the enzyme, but usually not at the active site.
- The noncompetitive inhibitor reacts either remote from or very close to the active site. The net effect of a non competitive inhibitor is to change the shape of the enzyme and thus the active site, so that the substrate can no longer interact with the enzyme to give a reaction.
- Non competitive inhibitors are usually reversible, but are not influenced by concentrations of the substrate as is the case for a reversible competitive inhibitor.

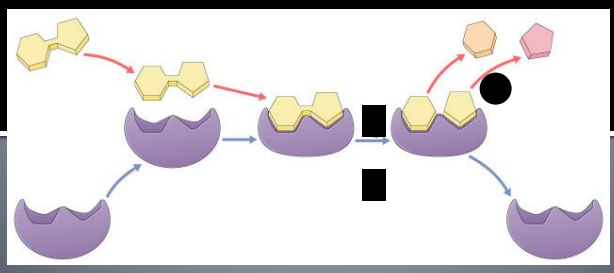
Inhibition



For enzymes…

What matters?

SHAPE!



QUESTION AND ANSWER

What role do enzymes play in living things and what affects their function?

Essential Question:

What are the basic chemical principles that affect living things?